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# DESIGN, DEVELOPMENT AND FIELD TESTING OF A MOBILE NINE UNIT HIGH VOLUME AIR SAMPLER ARRAY

FINAL REPORT

TO

ALBERTA ENVIRONMENT

by

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## OVERVIEW

A mobile nine unit high volume air sampler array has been built and field tested. Eight of the samplers were individually triggered according to wind direction. The ninth was directionally independent and operated at wind speeds below a pre-set cutoff. Elapsed time counters on each sampler recorded the period of operation. Thus atmospheric concentration could be determined and wind rose patterns constructed.

Particulate matter was separated into six sized fractions which are relevant to dust inhalation by humans. Chemically treated filters were used to trap $SO_2$.

Collected particulates and $SO_2$ were subjected to stable isotope ratio analysis (SIRA). Particulates were examined using scanning electron microscopy and electron probe x-ray fluorescence.

The tests were generally successful despite the fact that the electronics supplied for triggering the units did not perform up to expectations. It was found that the concentrations, character of the particulate matter, and isotopic compositions of samples taken at 1.5m above ground, varied significantly with wind direction.

A possible criticism of the approach is that the winds aloft are seldom in the same direction as at "nose level". However, it must be emphasized that data at this level are important from the viewpoint of human health studies. The unit would have limited ability to identify sources if only concentrations and ground level wind direction were taken into account. Fortunately, the

addition of sulphur isotope analyses increases the reliability of source identification.

Whereas the unit does not eliminate the need for comprehensive meteorological data, it can play a highly important role in atmospheric pollution investigations.

This array and earlier prototypes were used advantageously in three regional studies in Alberta. They involved collection of baseline data (Teepee Creek)(Krouse, 1979; Krouse and Case 1981), monitoring atmospheric sulphur compounds near an active sour gas plant (Whitecourt) (Krouse et al, in press), and documenting changes in atmospheric S-compounds following the shutdown of a long term $SO_2$ emitter (Valleyview) (Krouse and Case 1983).

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## 1.0 INTRODUCTION

The possible impact of industrial sulphurous emissions on the environment are manifold; soil and water pH may be lowered, the sulphur content of soil, water, air and biotic systems may increase, and the diversity and dynamics of biological communities can change. Although this is accepted and understood in general terms, the fate and full impact of anthropogenic air pollutants are still far from being thoroughly understood.

The type or source of atmospheric pollutant arriving at a monitoring site is dependent upon wind direction. However, the wind speed and direction at the top of a gas plant stack may be different from that at ground level several kilometres away or at higher elevations. It is entirely possible for sulphur dioxide emitted by a source to the north to arrive at a monitoring site on a westerly wind.

To assess the relationship between wind direction, and pollution source it has generally been the practice to obtain meteorological data concurrently with quantitative pollutant sampling using devices insensitive to wind direction, e.g., lead peroxide cylinders, autometers, single high volume samplers. With this approach, there are problems relating pollution parameters to given meteorological events or sources. This is especially true if there is no dominant prevailing wind direction. In principle, such problems should be reduced if the data acquisition is determined by prevailing wind direction and speed.

In order to check the relationship between wind direction and source, Stable Isotope Ratio Analysis (SIRA) was employed. Variations in the $^{34}S/^{32}S$ abundance ratio have been used to

"fingerprint" sulphur from various sources. These variations are expressed on a $\delta^{34}S$ scale defined as

$$\delta^{34}S \text{ in } ‰ = \left[ \frac{[^{34}S/^{32}S]_{sample}}{[^{34}S/^{32}S]_{meteorite}} - 1 \right] \times 10^{3}$$

where ‰ = parts per thousand or per mil and $[^{34}S/^{32}S]$ is the relative number of $^{34}S$'s to $^{32}S$'s. Application of SIRA to sulphur compounds have included evaluations of uptake by vegetation from the atmosphere and soil, penetration of pollutants into the soil, identification of emitters, microbiological $H_2S$ production, and agricultural transformations of sulphur compounds (Case and Krouse 1980; Chambers et al., 1976; Krouse 1977, 1979, 1980; Krouse and Case 1981, 1983; Krouse et al, in press; Laishley et al., 1976; Winner et al., 1977, 1978, 1981;

It occurred to us that wind-directionally controlled high volume sampling combined with stable isotope determinations would be an effective tool for characterizing sulphur compounds associated with ground level air movement. Further, techniques such as x-ray fluorescence, neutron activation analysis (NAA), isotopic analysis of other elements, and particle sizing can also be used in combination with wind directionally controlled air samplers to characterize many pollutants.

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## 2.0 PREVIOUS HIGH VOLUME AIR SAMPLER ARRAYS

In 1975, the Whitecourt Environmental Study Group (Legge at al., 1981; Krouse et al., in press), utilized SIRA (stable isotope ratio analysis) to demonstrate the effect of wind direction on the source of sulphur dioxide reaching a monitoring site. One hivol sulphur dioxide sampler was operated on a 16m scaffold in order to study the effects of sulphur dioxide on midcrown and upper crown foliage of a mature lodgepole pine stand.

The nearest industrial source emitted sulphur dioxide characterized by an average $\delta^{34}S$ value of 24 $^{o}/_{oo}$. On September 18, the wind was from the NW and the sulphur dioxide had a high $\delta^{34}S$ value corresponding to emissions from the upwind source (Figure 1). On September 19, the wind shifted easterly and the $\delta^{34}S$ value and concentration immediately decreased. From September 20 onwards, the wind swung southerly, then southwesterly to westerly with corresponding increases in $\delta^{34}S$ values and sulphur dioxide concentrations as the contribution from the industrial source to the NW increased.

When the data were plotted on a polar diagram (Figure 2), with the $\delta^{34}S$ values as the radial coordinate and the angular coordinate corresponding to compass direction, the source of sulphur dioxide emissions to the NW was clearly indicated. It was also realized that luck had played a significant role in recording such a major synoptic event with relatively few uncertainities in the wind direction, during which the sampling filters had to be exposed for over six hour intervals.

The Whitecourt project emphasized the inefficiency of the

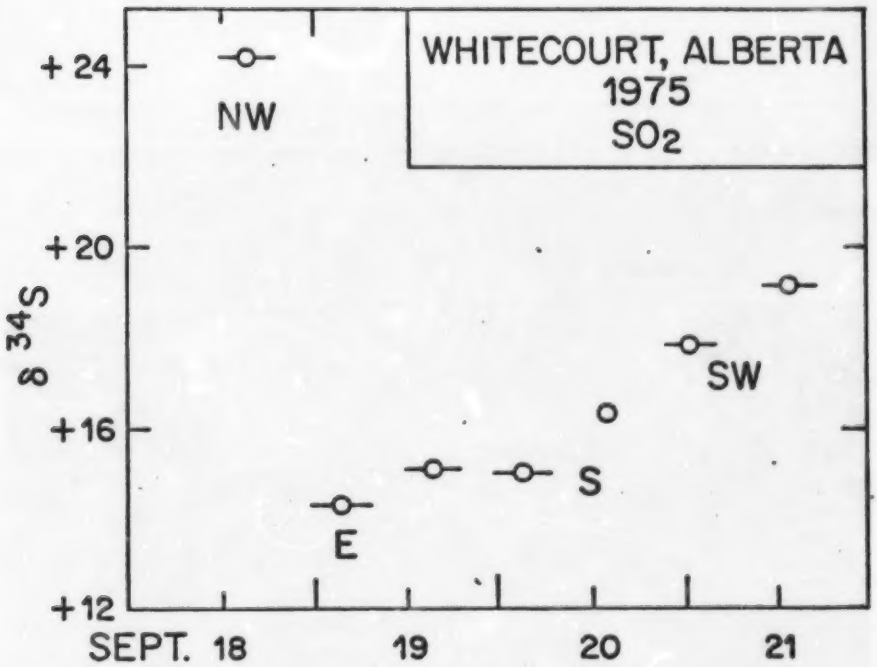



Figure 1. Scatter plot of $\delta^{34}S$ values of atmospheric sulphur dioxide as a function of wind direction at the West Whitecourt intensive study site for the period September 18-21, 1975.

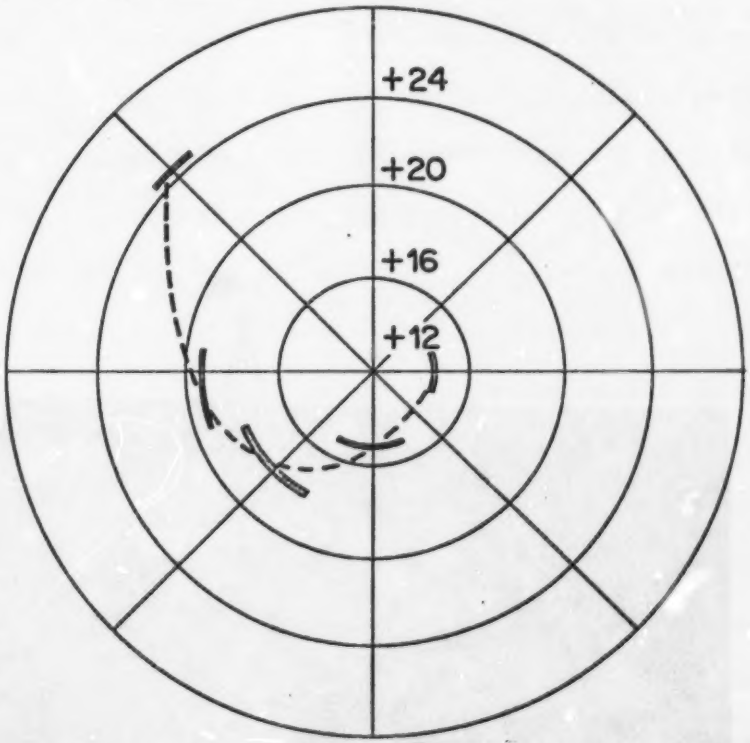



Figure 2. Polar plot of $\delta^{34}S$ values of atmospheric sulphur dioxide as a function of wind direction at the West Whitecourt intensive study site for the period September 18-21, 1975.

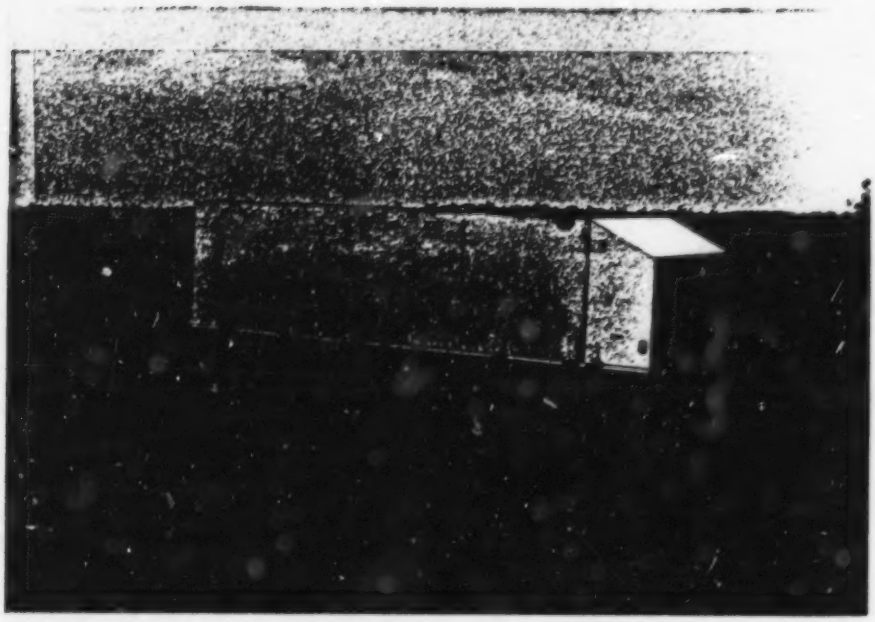


Figure 3. Hivol sampler array trailer as it appears closed up and ready to travel.

Figure 4. Trailer mounted nine unit hivol sampler array as it appears when set up and collecting samples in the field.

collecting samples and meteorological data separately, and integrating them later. If the wind changed direction many times during the acquisition of a sample by a continuously operating hivol, it would have been impossible to construct Figure 1. Based on this experience, an array of hivol samplers, each of which responded to a selected wind direction was conceived.

In 1976, studies resumed in the Whitecourt area (Legge et al., 1978). An array of four hivol samplers was developed within UNISUL (The University of Calgary Interdisciplinary Sulphur Research Group) and tested on a tower at a height of 20m. The individual samplers were triggered by a simple wiper-contact system within the head of a wind vane. As expected, some samples were insufficient for isotopic analysis because the wind rarely came from those directions during the sampling period. Other problems were also encountered. At low wind velocities, the wind vane switch system did not respond to a change in wind direction because of internal friction. As a result, the wrong sampler was sometimes running.

In 1978, the four unit sampler array was used for ground level sampling in the Teepee Creek area (Krouse 1979; Krouse and Case 1981). The $\delta^{34}S$ value of the sulphur dioxide emissions was known to be 24 ‰. It was found that the directions of highest sulphur dioxide concentrations did not necessarily correspond to the downwind direction for the gas processing plant. The sulphur content of airborne particulate matter corresponded to the sulphur dioxide concentrations for each direction but there was no consistent relationship among their isotopic compositions. It

was also found that the higher $\delta^{34}S$ values (i.e., those approaching the value of the nearby sulphur dioxide emissions) did not correspond to the downwind direction from the industry. It should be noted that the sulphur dioxide levels in the Teepee Creek study were well below the ambient air quality standards for Alberta and interpretations were possible at these subcritical concentrations.

Figure 5. Flow control instrumentation on hivol air sampler.

## 3.0 OBJECTIVES

The specific objective of this project was to design, build and test a prototype of a mobile wind directionally controlled programmable sampling array to quantitatively collect windblown dust, inhalable particulate matter, and sulphur dioxide. This was to involve:

(1) construction of a nine unit hivol air sampling array capable of continuously sampling known volumes of air at a constant flow rate according to wind direction;

(2) equipping each hivol with a device to collect and separate airborne dust, pollen and respirable particulate matter;

(3) developing a wind speed-direction control system to activate one of eight hivols according to wind direction; the ninth hivol to be activated only when the wind speed is less than 3 km/h regardless of wind direction;

(4) mounting the equipment on a flatbed trailer;

(5) field testing of the array;

(6) preliminary SIRA testing of collected samples.

## 4.0 DESIGN CONSIDERATIONS AND CONSTRUCTION

After surveying the published literature, consulting other air quality experts, and reviewing the previous field experiments (section 2.0) above), the following conclusions were reached concerning atmospheric sampling of airborne particulate matter and sulphur dioxide:

(1) Five stage sizers should be used to separate airborne particulate matter into nonrespirable and respirable size classes. The use of an Andersen particle sizers in the Teepee Creek area revealed considerable variations in particle size and isotopic compositions (Krouse and Case, 1981).

(2) The operating conditions should be such that the size classes in (1) correspond to recognized degrees of penetration into the human respiratory system.

(3) Attempts should be made to characterize the particulates beyond their aerodynamic size distribution; elemental composition, abiotic vs biotic etc.

(4) Low sulphur content glass fibre filters should be used in the hivol air samplers because of the low sulphur content of the samples being collected.

(5) The practice of using cellulose fibre filters treated with triethanolamine and potassium hydroxide (TEA-KOH) to collect sulphur dioxide passing through hivol air samplers was as good or better than other techniques of quantitative sulphur dioxide collection.

Experience gained with the earlier sampler arrays (reviewed in Krouse, Legge and Brown, 1983) led to the design and construction of the present trailer-mounted nine hivol sampler array as shown in Figures 3 and 4. A list of the major components is given in Appendix 1. The equipment selected should not be considered as an endorsement of the products. Comparable equipment is available from a number of manufacturers and our selections were dictated solely by competitive bids.

In previous array designs, it was occasionally found that if the wind was from a direction close to the switching point, the two hivol samplers would rapidly switch on and off. Also, if an wind eddy or gust switched the wind vane momentarily, the samplers would turn on and off in quick succession but the driving motors would not have time to reach operating speed. To correct this problem, a delay was incorporated into the switching system. In this way, the sampler operating would not shut down unless the wind direction had remained changed for a defined period (1 to 5 min).

Each hivol sampler was equipped with a flow controller and an elapsed time meter (Figure 5). Therefore, once calibrated for a certain flow rate (e.g., 1133 *l*/min), the electric motor would automatically compensate for filter loading. Using the elapsed time reading, the flow rate, and the mass of sulphur collected, the concentration of sulphur in the volume of air sampled could be determined. The problem of insufficient sample sizes could be overcome by leaving the filters in a sampler until a sufficient time was recorded by the time lapse meter.

Each sampler was also equipped with a five-stage cascade impactor (Figure 6) to selectively separate and collect airborne particulate matter in five aerodynamic size classes. The size classes in microns, going from the top to the bottom filter were >7, 3.3 to 7.0, 2.0 to 3.3, 1.1 to 2.0, and <1.0. These size classes were considered to be important because they correspond to the size classes of particulate matter found on the skin surface, trachea and primary bronchi, secondary bronchi, terminal bronchi and alveoli, respectively. Subsequent to the bottom slotted filter, a nonslotted glass fibre filter was inserted to remove any very fine particulate matter. Below each particulate matter filter pack, there was a TEA-KOH treated backup filter to collect sulphur dioxide. It was assumed, on the basis of published reports, that the adsorption of sulphur dioxide onto the particulate filters would be negligible.

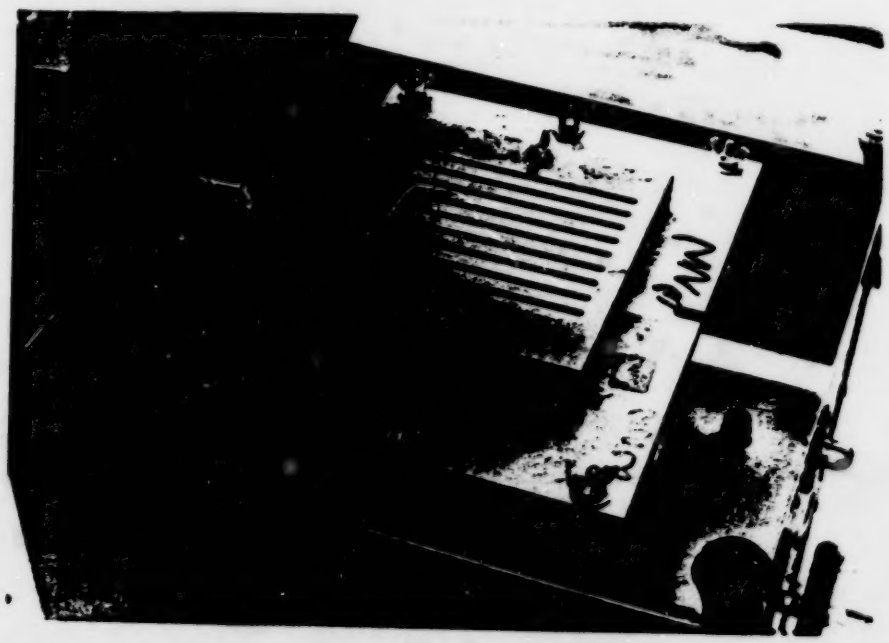


Figure 6. Each hivol air sampler was equipped with a 5 stage slotted cascade impactor to permit collection of 5 size classes of suspended particulates.

## 5.0 FIELD TRIALS

The nine unit hivol sampling array was field tested in the vicinity of Crossfield, about 50 km N of Calgary, from 18 March to 14 April, 1980. The Crossfield and Balzac gas plants were nearby.

Each hivol sampler was allowed to run for minimum of 500 minutes in total to insure sufficient material was collected for analysis. Subsequent to collection, the particulate filters and TEA-KOH filters were analysed to determine the stable isotopic composition of the sulphur collected (Krouse and Case 1981). Although not called for by the original terms of reference, selected sets of particulate filters were examined by scanning electron microscopy to further characterize each size class. SEM permitted visual comparison of the particulate matter on different filters. The scanning electron photomicrographs were obtained using the Cambridge 600 SEM in the Department of Geology and Geophysics, The University of Calgary. Qualitative elemental analyses were performed using a Kevex energy dispersive analytical system (based on intensity estimates of characteristic x-ray transitions). Use of an electron probe and x-ray fluorescence detector during SEM permitted characterization on the basis of the relative amounts of Al, Au, Ca, Cl, Fe, K, Na, Mg, S, Si, Ti, and Zn.

## 6.0 RESULTS

In a letter to Dr. Harby Sandhu, dated 1980-05-08, it was reported that "An array of nine hi-vol air samplers, controlled by an electronic switching device, was assembled. The switching gear was field tested and after minor alterations to the manufacturers design, the electronic switching apparatus was capable of controlling a system of nine hi-vol air samplers, fitted with particle sizers, using signals from wind speed and objective as set out in the terms of reference:". It was further pointed out that the automatic continuous sampling array was, at the request of Alberta Environment, being used in an investigation of sulphur dioxide impact in the region of Valleyview, Alberta.

The satisfaction of the funding agency with the hivol sampler array concept and design was so favourable that the array was made a major component of the Valleyview stable sulphur isotope study even before the field trial results could be analyzed and assembled into a report.

### 6.1 SAMPLER ARRAY PERFORMANCE

In terms of transport, the trailer with enclosure proved ideal for slow speed movement and could travel over relatively rough terrain, e.g., cultivated fields. Highway travel, however, proved difficult due to side wind buffeting and fish-tailing at speeds over 75 kmph.

In field operation, the unit performed essentially as predicted. As might be expected in testing a new prototype, a few minor problems were encountered, For example, despite the fact

the trailer had a heavy duty deck, sagging occurred at the edges due to the weight of the hinged side panels. When closing the trailer for transport, it was necessary to jack up the rear to properly align the panels for inserting their locking pins. Some components were not properly selected for outdoor usage. The hinges on the panels were steel and, despite oiling, quickly rusted to the point where they were difficult to close. Stainless steel hinges would be better.

Major problems were encountered with the array controller device as supplied by the manufacturer. It proved incapable of handling the power surges during the startup of the hivol sampler motors. This was aggravated by fluctuations in the voltage available and power losses in the very long extension cords. When the voltage reaching the relays was too low, they tended to chatter rather than remaining firmly closed.

## 5.2 PRELIMINARY ISOTOPIC DATA

Preliminary tests were carried out near Crossfield, Alberta during the period March 18 to April 14, 1980. The particulates collected on the filters of the five stage slotted cascade impactor were treated with a $HI-H_3PO_2-HCl$ mixture to generate $H_2S$ which was precipitated as $Ag_2S$ and subsequently converted to $SO_2$ for mass spectrometric isotope analyses. The TEA-KOH treated filters which had trapped $SO_2$ were oxidized in a $H_2O_2$ solution and filtered into a $BaCl_2$ solution. The $BaSO_4$ precipitate was reduced with the $HI-H_3PO_2-HCl$ mixture and $SO_2$ prepared for isotopic analysis as described above. The isotope data are given in Table I and as polar diagrams in Figures 7 to 13.

**Table I.** Sulphur Isotope $\delta^{34}S$ Values for Sulphur Dioxide and Sulphate in Six Size Classes of Airborne Suspended Particulate Matter Collected Near Crossfield, Alberta, 18 March to 14 April.

| Filter | NNE | ENE | ESE | SSE | SSW | WSW | WNW | NNW | Local |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 14.8 | 14.7 | 19.4 | 16.4 | 16.6 | 14.0 | 18.8 | 13.6 | 7.0 |
| 2 | 8.6 | 18.2 | 17.1 | -- | 6.5 | 12.0 | 13.2 | 17.4 | 7.7 |
| 3 | 13.5 | 14.8 | 16.0 | 14.1 | 14.5 | 13.6 | 15.3 | 11.3 | 9.4 |
| 4 | 8.3 | 16.4 | 15.6 | 16.3 | 15.5 | 9.5 | 13.1 | 16.6 | 10.3 |
| 5 | 14.6 | 16.2 | 16.6 | 13.9 | 18.9 | 13.5 | 12.3 | 11.8 | 13.2 |
| 6 | 12.0 | 10.8 | 6.1 | 7.7 | 3.5 | -3.4 | -2.0 | 12.9 | 3.3 |
| TEA | 27.6 | 12.1 | 16.3 | 12.7 | 15.2 | 22.4 | 23.4 | 14.1 | 9.3 |

It is seen in Table I that for the low wind speed sampler (local) and 6 out of the 8 different wind directions, the $\delta^{34}S$ values are lowest for the smallest size particulates (Filter 6). In 7 out of 9 cases, the $\delta^{34}S$ values of the $SO_2$ were quite different from those of the preceding particulate filter (Filter 6). This suggests that oxidation of $SO_2$ on the particulate filters was not a serious problem.

In three samplers (NNE, WSW, WNW) the $\delta^{34}S$ values of the $SO_2$ were more positive than for the particulates collected in the same sampler. For all other samplers, the $\delta^{34}S$ values of the $SO_2$ fell within the range of the co-collected particulates.

Figure 7.

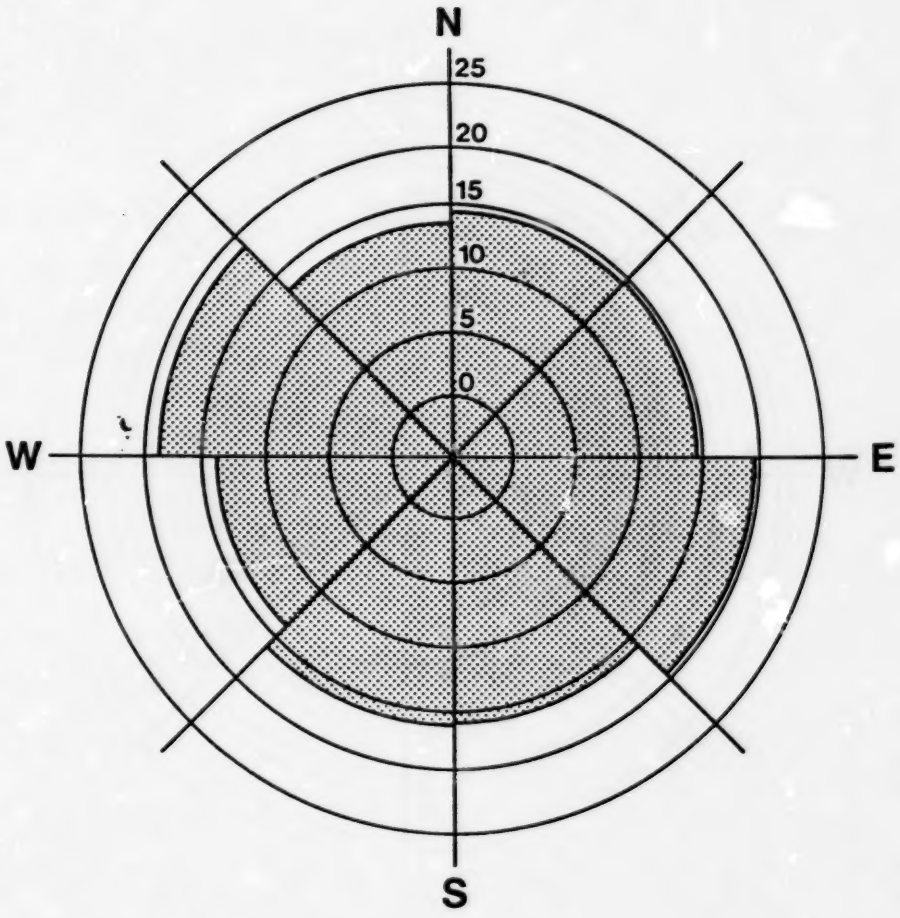
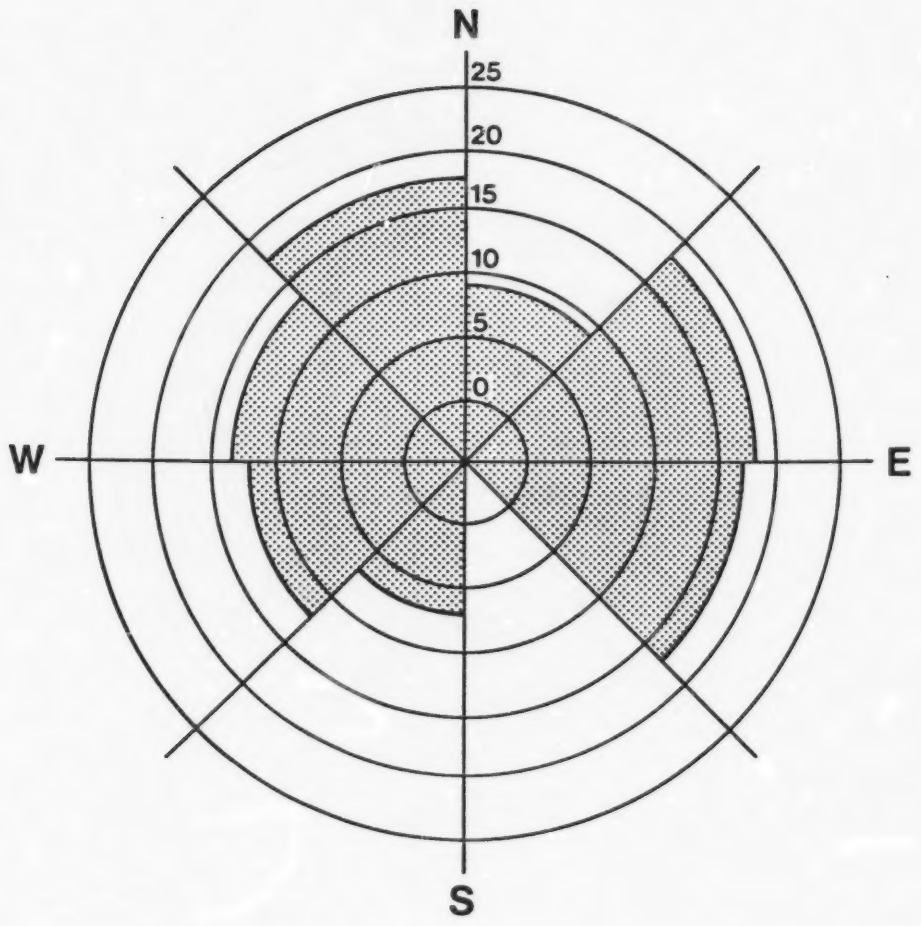


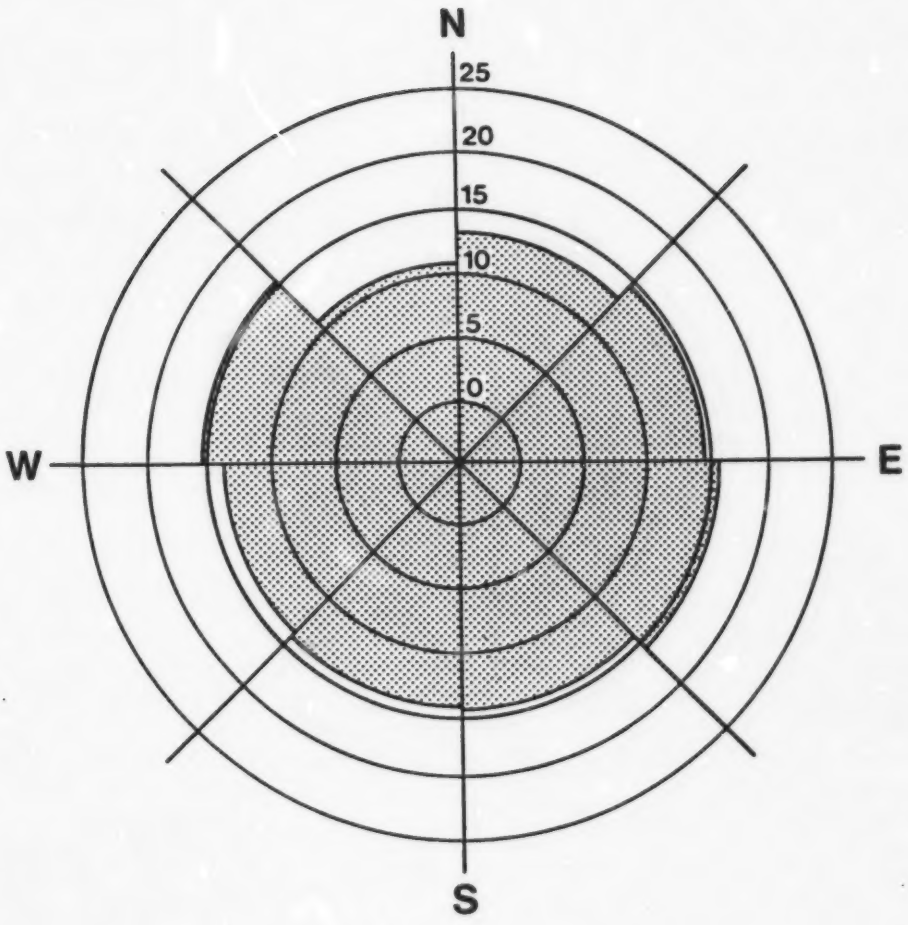

Figure 7 shows that particulate matter with an aerodynamic diameter of >7 microns (Filter 1) was generally very uniform with respect to $\delta^{34}S$ value, and only showed an increase when the wind was coming from the WNW or the ESE. The $\delta^{34}S$ value in the local sampler was significantly lower.

Figure 8.



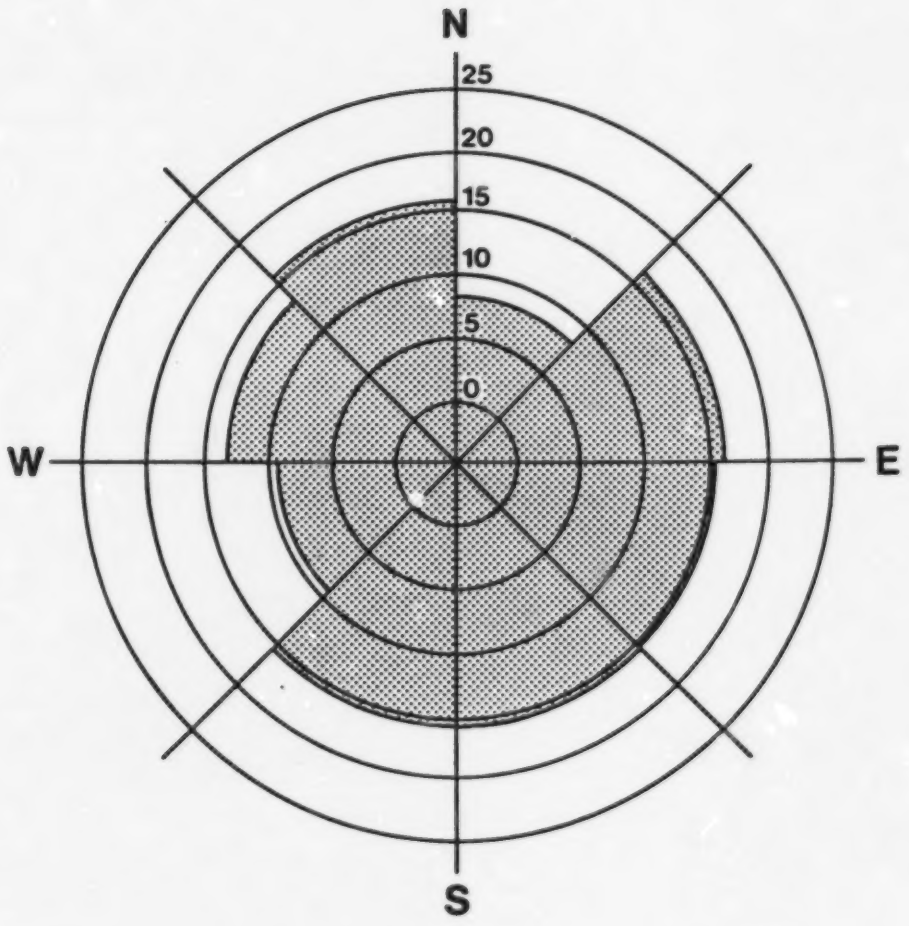

Particulate matter with a diameter between 3.3 to 7.0 microns (Filter 2) (Figure 8), collected from the different sectors, did not have uniform $\delta^{34}S$ values. Rather, particles from the NNE, SSE and SSW were depleted in $^{34}S$ relative to particles coming from other directions. With the exception of the SSW, the $\delta^{34}S$ value for the local sampler was lower.

Figure 9.



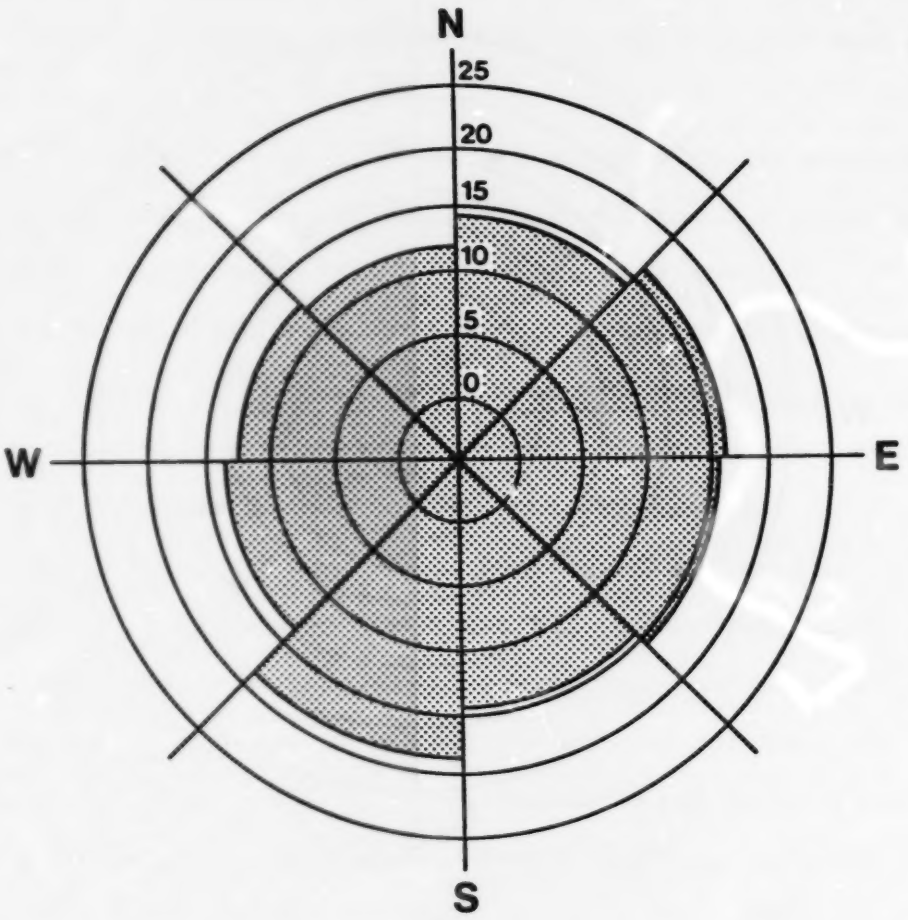

Particulate matter with a diameter in the range of 2.0 to 3.3 microns (Filter 3) had remarkably uniform $\delta^{34}S$ values, regardless of the wind direction (Figure 9). Again, the $\delta^{34}S$ value is lowest in the local sample.

Figure 10.



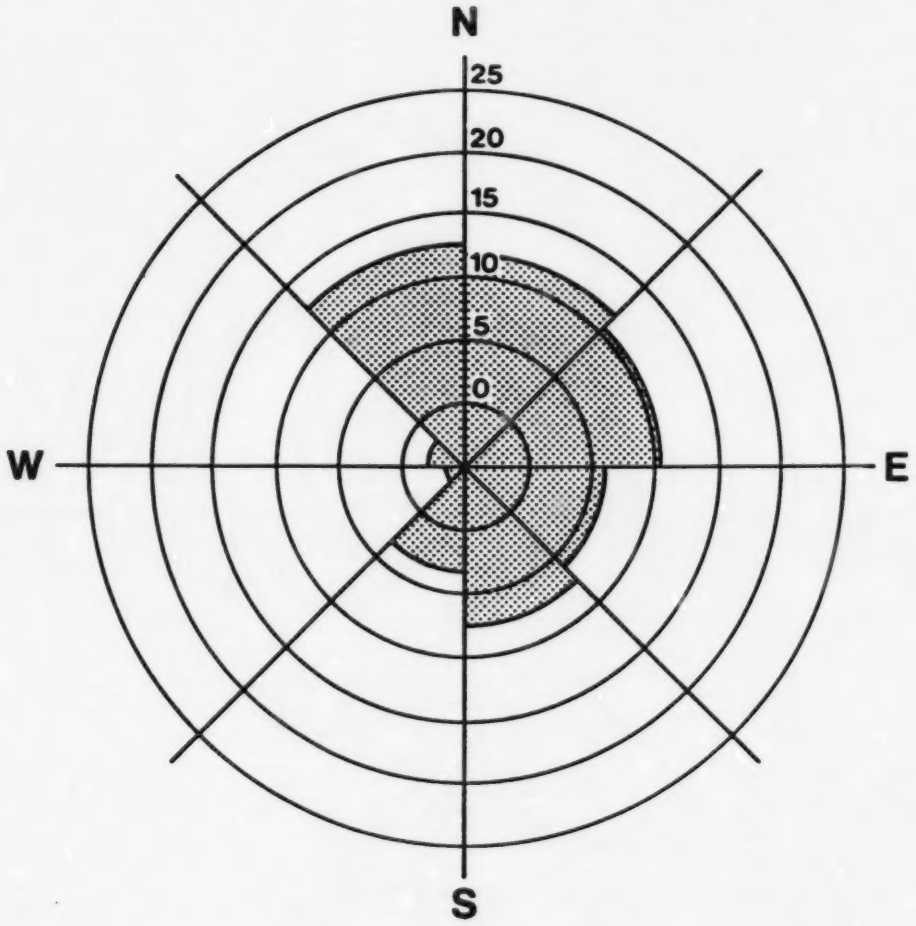

Particles in the diameter range of 1.1 to 2.0 microns (Filter 4) also had relatively uniform $\delta^{34}$ values regardless of wind direction, with the exception of NNE and WSW (Figure 10). These particles had lower $\delta^{34}$ values than even those from the local sampler.

Figure 11.




Particles in the size range 0.1 to 1.1 microns (Filter 5) have fairly uniform $\delta^{34}S$ values with the lowest value in the NNW sector (Figure 11). Particles from the SSW were isotopically slightly enriched in $S^{34}$. That may be a function of emissions from cars and industry in Calgary which burn petroleum products.

Figure 12.




Very small particles (<0.1 microns) (Filter 6) carried to the sampling site by winds from the WNW and WSW were distinctly depleted in $S^{34}$ relative to all other particle sizes and directions (Figure 12). The very small size of these particles would permit their transport over long distances.

Sulphur dioxide was collected on cellulose filters impregnated with KOH and triethanolamine (TEA). Figure 13 shows that the sulphur dioxide collected was sometimes isotopically distinct from any size class of particulate matter in the same sampler. It had a larger range of $\delta^{34}S$ values with the maximum being 27.6 ‰.

The higher enrichments in $^{34}S$ are diagnostic of emissions from sour gas processing plants. Emissions from the Crossfield plant 4.5 km to the NNW, have $\delta^{34}S$ values near 29‰ whereas those from the Balzac plant 10 km to the SE are near 17‰. Therefore, it is reasonable that $\delta^{34}S$ values greater than 20‰ were observed in the western sector while values near 16‰ were observed for the ESE sampler. However, the $\delta^{34}S$ value near 29‰ in the NNE sector is not so readily interpreted. Does the $SO_2$ in the NNE sector reflect emissions from Crossfield located to the NW as a consequence of a complex wind system? Or, did the $SO_2$ come from the Lone Pine Creek plant 45 km to the NE which also has $\delta^{34}S$ values near 30‰. A knowledge of atmospheric circulation is required for an unambiguous interpretation. The isotopic data are nevertheless useful. The finding of the $\delta^{34}S$ value near 29‰ in the NNE sector is very important and particularly emphasizes how conclusions based only on concentrations and ground level winds could be very misleading. $\delta^{34}S$ data can substantiate or negate interpretations of ground level sampling programmes.

Another important observation is that the high $\delta^{34}S$ values for $SO_2$ were not accompanied by correspondingly high $\delta^{34}S$

values for particulates. This suggests that the particulates were not related to $SO_2$ emissions. Further, failure to find particulates with $\delta^{34}S$ values greater than 25‰ suggests absence of significant sulphur dust from the Crossfield plant in the collectors.

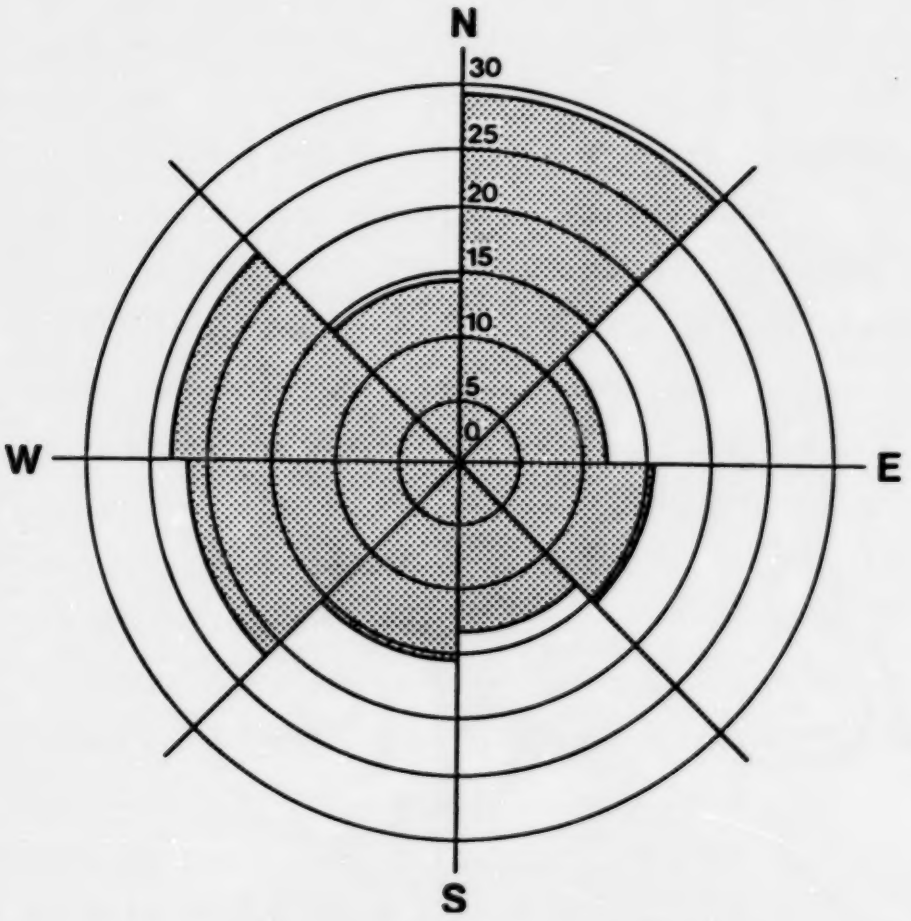



Figure 13. $\delta^{34}S$ values of sulphur dioxide according to wind direction at monitoring site.

## 6.3 Scanning Electron Microscopy

Figures 14 to 25 are scanning electron micrographs of particulate matter collected from the SSW and WNW sectors. These sectors were chosen for study because it was felt that they might reflect particles from the direction of the Crossfield gas plant and the City of Calgary, respectively. Tables II and III present summaries of elemental relative abundance in the particulate matter determined by x-ray probe analysis.

Particles from the WNW, with an aerodynamic diameter >7 microns, were composed largely of Si with Ca, Al, K, and Fe being present in lesser quantities. Similar particles from the SSW were composed largely of Ca, with Si, Al, Fe, K, S, Na and Mg as minor components.

As in the case of the largest size class of particles (>7.0 microns), the second size class (3.3 to 7.0 microns) (Filter 2) from the WNW were composed primarily of Si, however, significant differences are apparent in the minor element composition. No K or Fe was detected, but Mg and S were present in significant quantities. Particles of this size class from the SSW were composed mainly of Si unlike the largest size class of particles. All other elements were comparable with the addition of Cl.

The third size class particles, 0.8 to 2.0 microns in diameter, from the NNW and SSW filters have very similar compositions: they typically consist primarily of Si, with lesser amounts of Ca and trace amounts of Na, Mg, Al, S, Cl, K and Fe.

The composition of the 0.4 to 0.9 micron particles from the fourth filter was similar for both directions with the principal

Table II. Relative Abundance of Elements Detected by X-Ray Fluorescence Analysis of Particulate Matter on SSW Filters

| Filter | Na | Mg | Al | Si | S | Cl | K | Ca | Fe | Ti | Zn | Au |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.5 | 0.5 | 17.5 | 48.0 | 1.7 | 0.0 | 9.2 | 80.5 | 10.5 | 0.0 | 0.0 | 0.0 |
| 2 | 5.3 | 1.7 | 22.8 | 87.5 | 6.8 | 6.8 | 9.2 | 42.5 | 7.3 | 0.0 | 0.0 | 0.0 |
| 3 | 8.0 | 2.5 | 15.5 | 97.0 | 0.0 | 0.0 | 4.5 | 36.3 | 3.2 | 0.0 | 0.0 | 0.0 |
| 4 | 15.0 | 0.0 | 16.8 | 99.9 | 10.3 | 9.5 | 6.8 | 22.3 | 2.8 | 0.0 | 0.0 | 0.0 |
| 5 | 10.8 | 2.0 | 18.0 | 99.9 | 13.5 | 0.0 | 8.8 | 20.8 | 2.5 | 2.0 | 1.3 | 0.0 |
| 6 | 9.8 | 5.0 | 10.8 | 87.6 | 4.2 | 1.0 | 8.8 | 47.4 | 0.0 | 0.0 | 0.0 | 0.0 |

Table III. Relative Abundance of Elements Detected by X-Ray Fluorescence Analysis of Particulate Matter on WNW Filters

| Filter | Na | Mg | Al | Si | S | Cl | K | Ca | Fe | Ti | Zn | Au |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 0.0 | 33.0 | 99.9 | 0.0 | 0.0 | 16.7 | 50.0 | 12.0 | 0.0 | 0.0 | 0.0 |
| 2 | 0.0 | 10.0 | 20.0 | 99.9 | 20.0 | 0.0 | 0.0 | 8.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3 | 9.6 | 2.4 | 16.4 | 99.9 | 1.8 | 0.6 | 7.0 | 19.8 | 1.4 | 0.0 | 0.0 | 0.0 |
| 4 | 8.5 | 3.8 | 14.3 | 99.9 | 15.5 | 0.0 | 8.0 | 21.0 | 2.5 | 0.0 | 0.0 | 0.0 |
| 5 | 7.8 | 2.5 | 27.5 | 98.3 | 42.8 | 0.0 | 14.8 | 47.3 | 9.8 | 0.0 | 0.0 | 0.0 |
| 6 | 6.9 | 1.4 | 15.0 | 80.1 | 11.3 | 0.0 | 9.9 | 29.1 | 3.0 | 0.0 | 0.0 | 15.3* |

* Possible contaminant during SEM sample preparation.

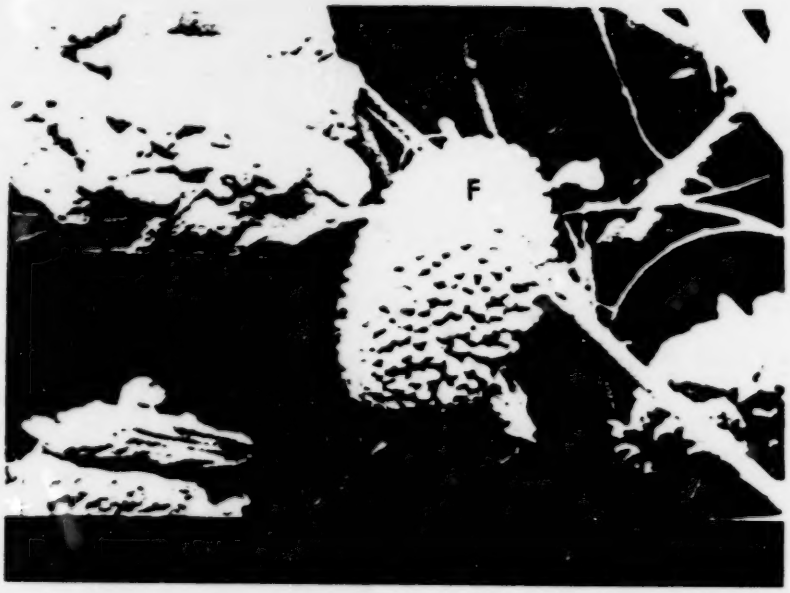
constituents being Si, and minor amounts of Na, Al, S, K, Ca and Fe. Certain differences are evident. Particles from the WNW contain Mg, whereas particles from the SSW lack it but contain 10 times as much Cl and S.

The 0.1 to 1.1 micron particles from both directions have about the same amounts of Na, Mg, and Si, but those from the SSW have about $^2/_3$ as much K, $^1/_2$ as much Ca, and only $^1/_4$ as much Fe. The particles from the SSW, however, contain traces of Ti and Zn, which were not found in particles from the WNW.

The elemental composition of the particles with an aerodynamic diameter <0.1 microns was nearly the same for both sectors, although those from the WNW had more Fe and less Ca. Particles from the WNW also contained traces of Au.

It must be realized that the analyses in Tables II and III are based on a few individual particles which may not represent the average composition of the collected particulate matter. The data are cited to illustrate that particulates associated with different wind directions display differences in elemental composition. The fact that the sulphur content is generally higher in the particles examined in the WNW filters justifies the use of SEM scanning techniques for obtaining more representative elemental compositions.

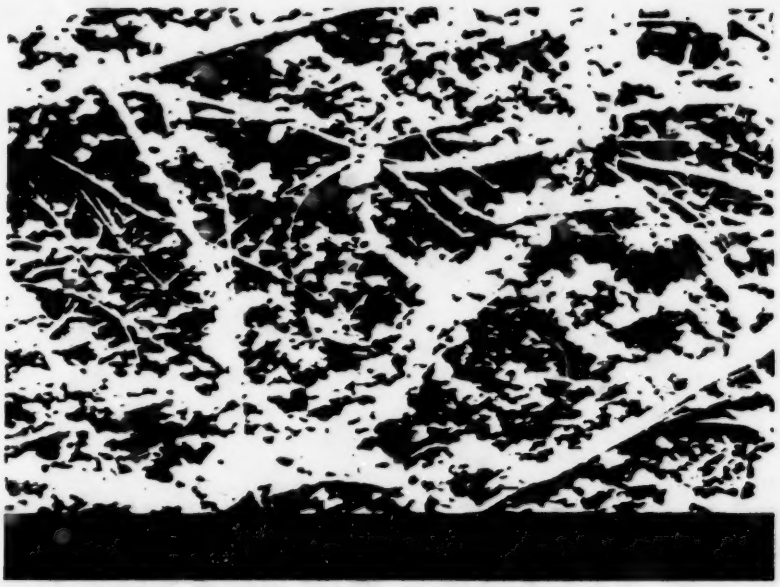
a



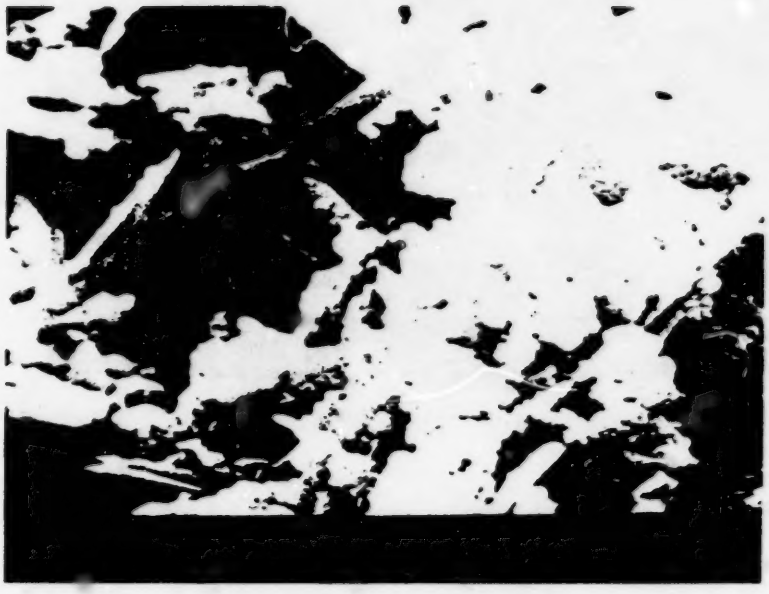

b

Figure 14(a) shows some of the largest particulates carried to the monitoring site from the WNW. Particle diameter ranged from 10 to >20 microns. Figure 14(b) shows the laminated structure of the particles from the WNW. The oblong tuberculate object is a fungal spore.

Figure 15 shows the particulate matter carried to the monitoring site from the SSW. Particles ranged in size from about 8 to >20 microns.

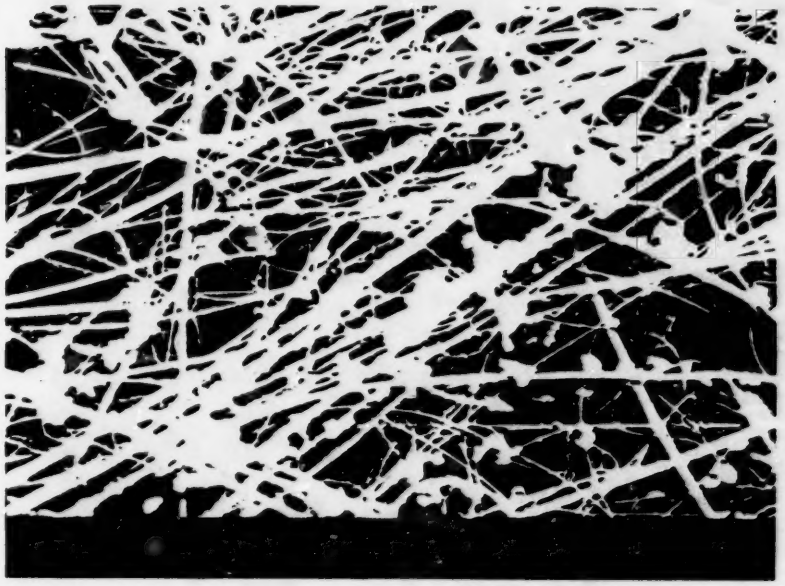


a

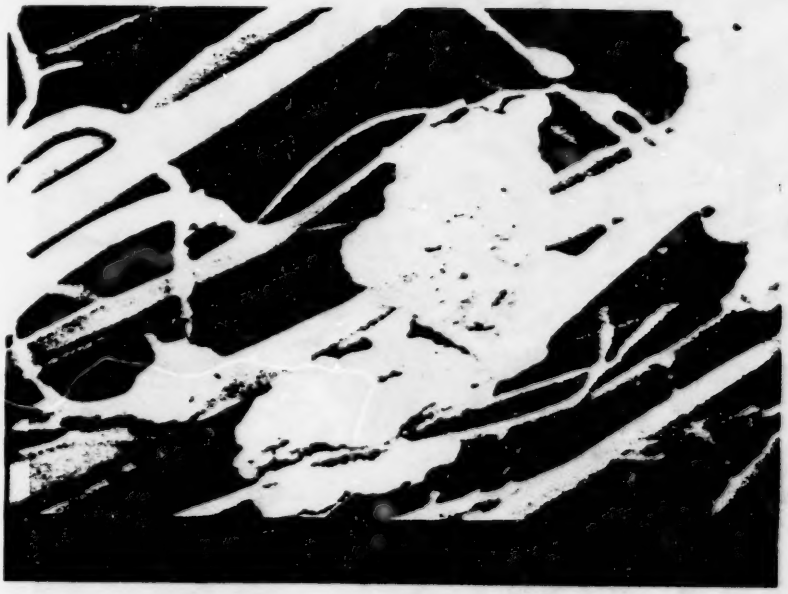


b

Figure 16(a) shows the second size class of particulate matter carried to the monitoring site from the WNW. Figure 16(b) shows in greater detail how individual particles are clumped together on the filter fibres. Individual particles range in size from about 2 to 4 microns.



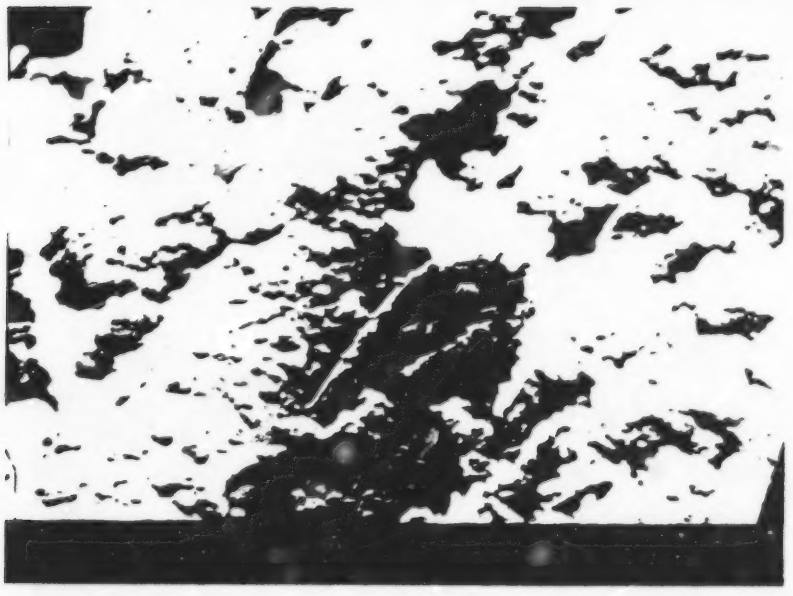
a



b

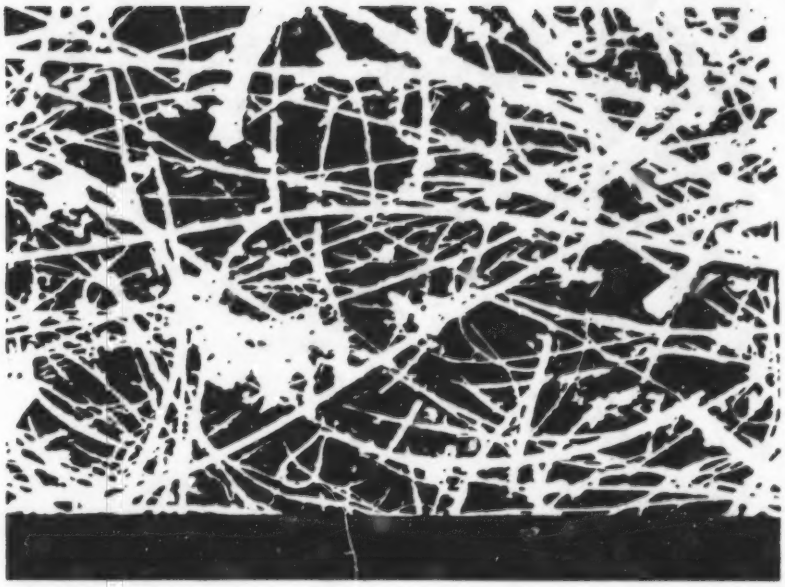
Figure 17(a) shows the second size class of particulate matter carried to the monitoring site from the SSW. Figure 17(b) shows the particles in greater detail, revealing a laminated structure similar to that seen in Figure 14(b).

a



b

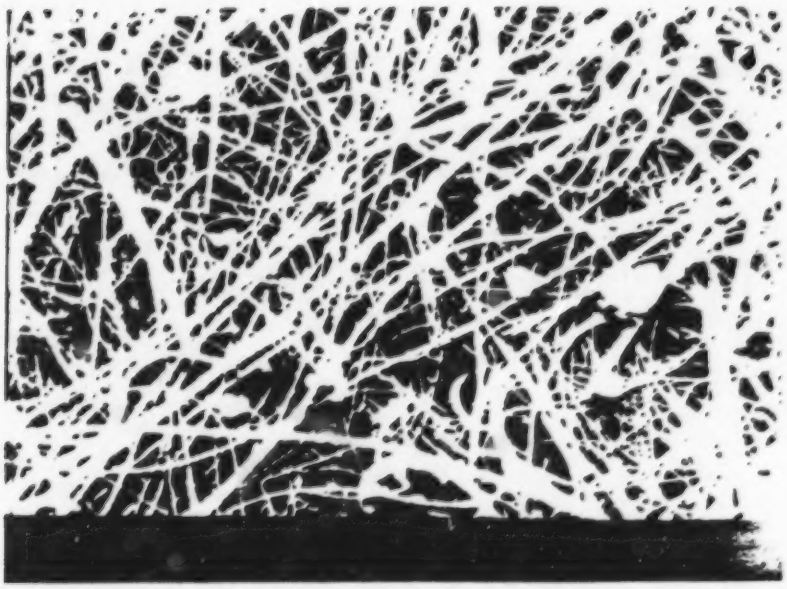
Figure 18(a) shows a large particle from the WNW direction that was able to make it onto the third size class filter (2.0 to 3.3 microns) (Filter 3) which typically collects particles >1 to >4 microns in diameter. Figure 18(b) shows the third size class particles in detail and reveals how they clump together on the filter.



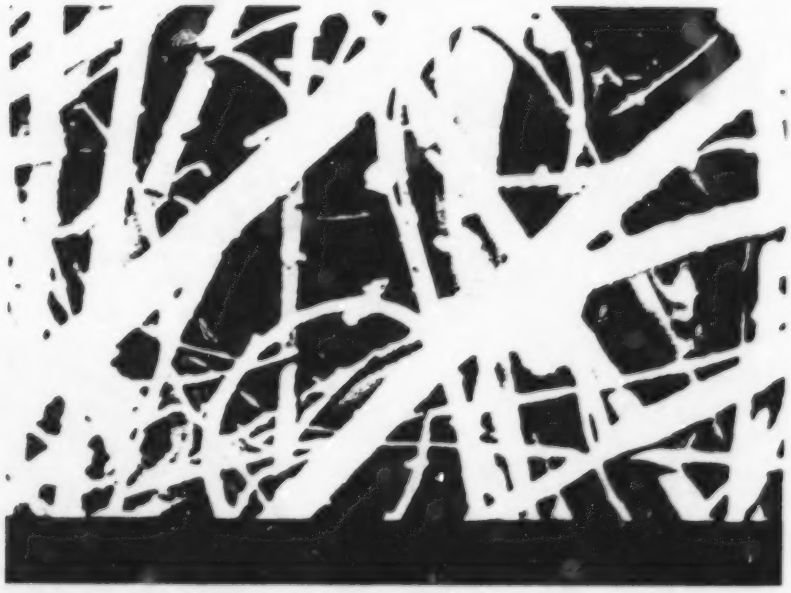
a

b

Figure 19(a) shows the third size class particles on the SSW filter. Figure 19(b) shows these particles in greater detail. The particles range in size from about 0.8 to 2.0 microns in diameter, the same range as for the NNW filter.

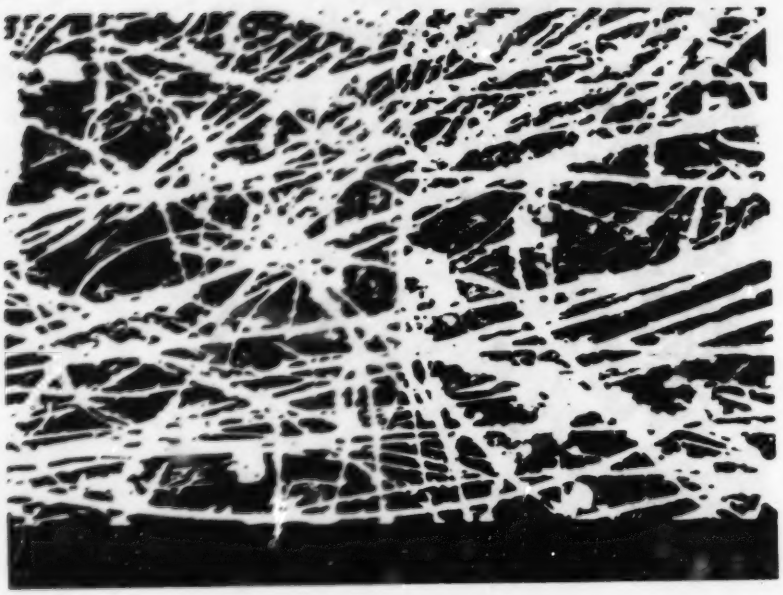


a

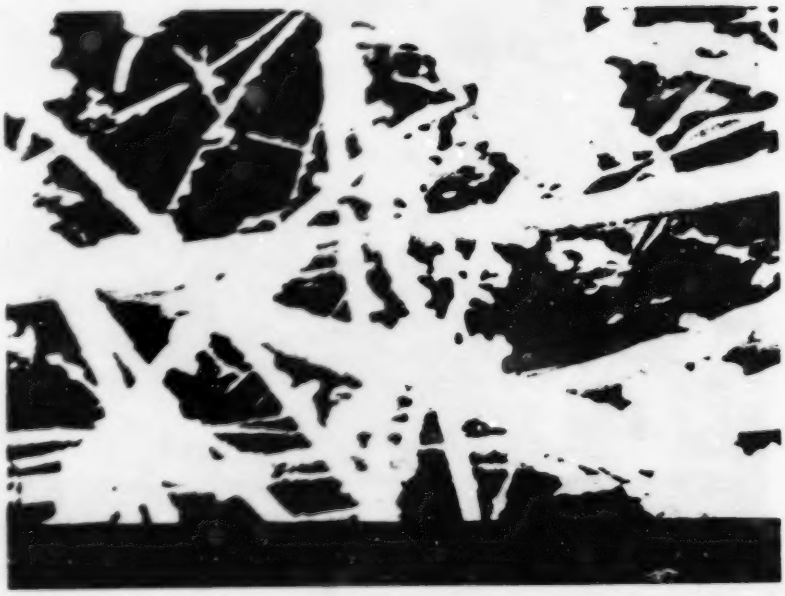


b

Figure 20(a) shows the fourth size class particles (1.1 to 2.0 microns) (Filter 4) carried to the monitoring site from the WNW. The majority of the particles are very small. Figure 20(b) shows that particles from the WNW were typically 0.4 to 0.9 microns in diameter but some were as large as 3 microns.

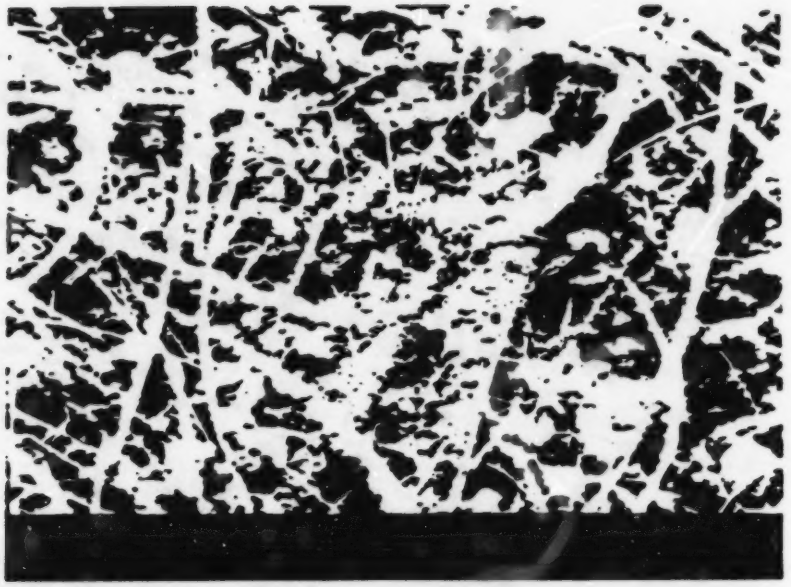


a

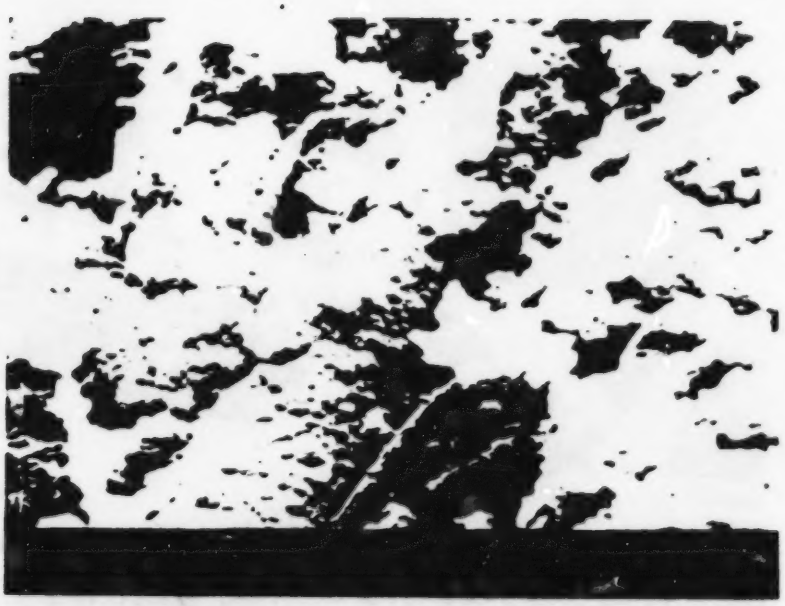


b

Figure 21(a) shows the fourth size class of particles from the SSW. Again, most of the particles are very small. Figure 21(b) reveals that most of the fourth size class particles from the SSW were about 0.5 microns in diameter.



a



b

Figure 22(a) shows the fifth size class of particles (0.1 to 1.1 microns) (Filter 5) carried to the monitoring site from the WNW. The majority of these abundant particles are very fine; < 0.5 microns in diameter [Figure 22(a)].

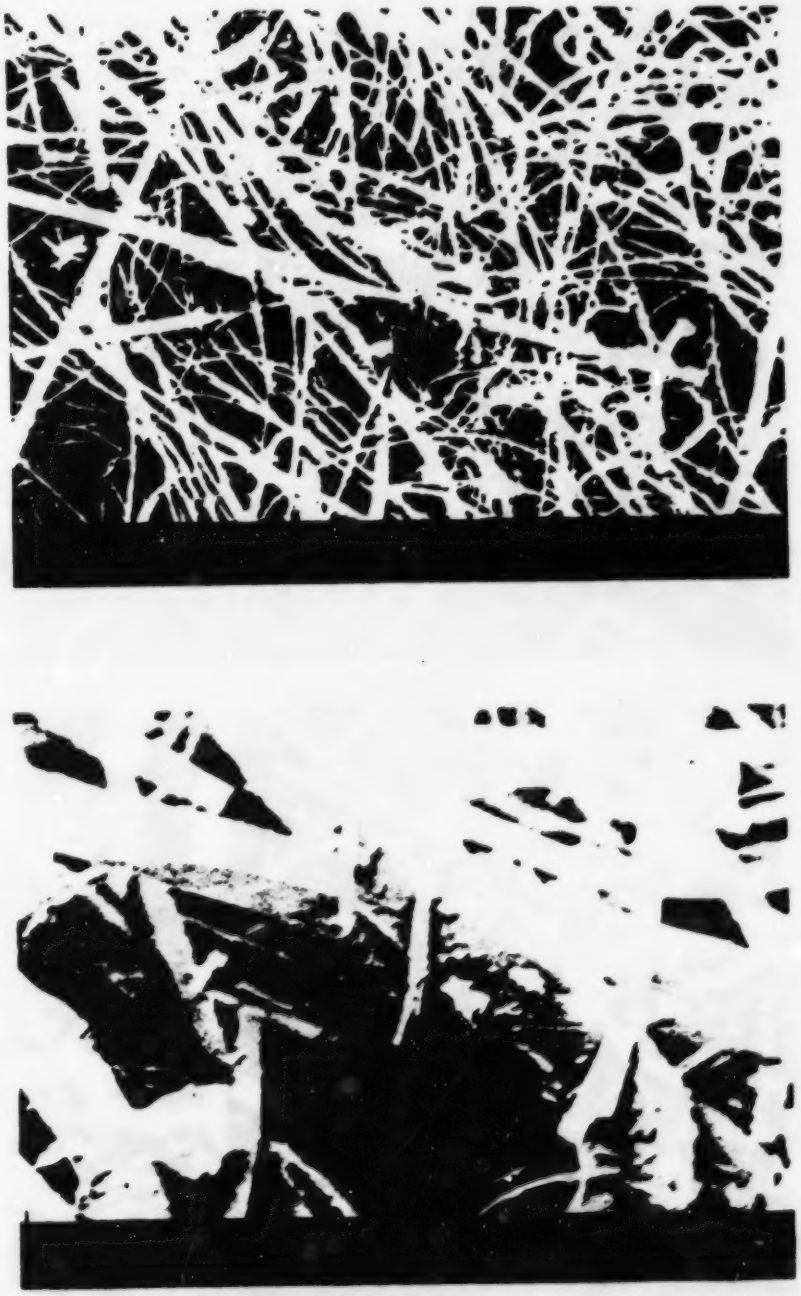
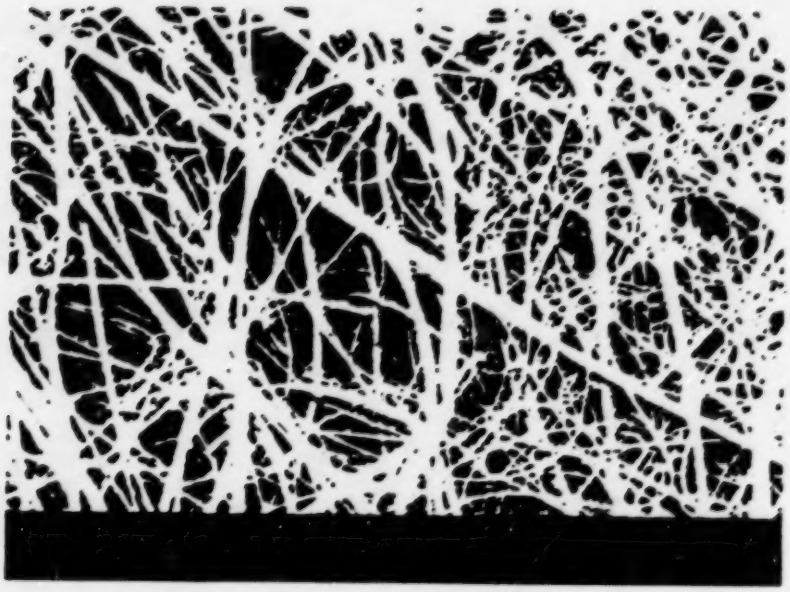


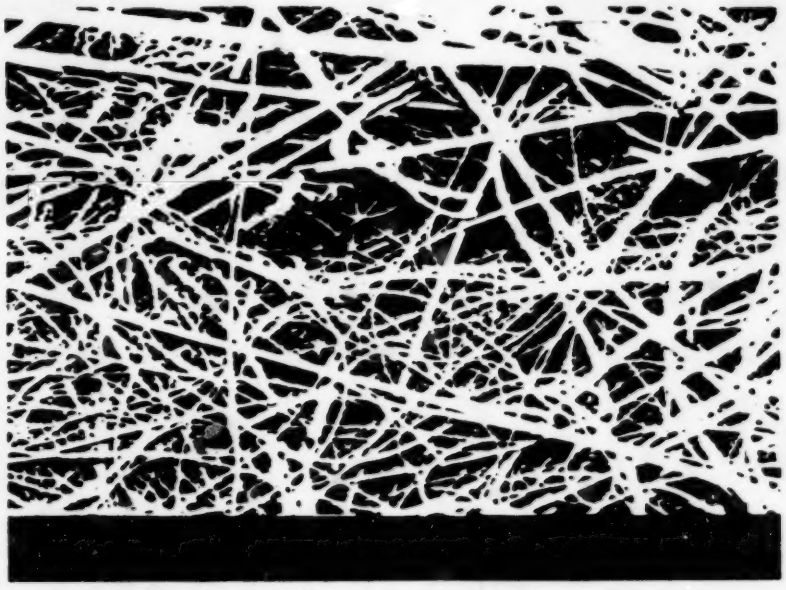

Figure 23(a) show the fifth size class of particles from the SSW. This size class of particles is almost totally absent when the wind is from that direction [Figure 23(b)].



a

b

Figure 24(a) shows the finest size class of particles (<0.1 microns) (Filter 6) carried to the site from the WNW. These particles are usually less than 0.2 microns in diameter [Figures 24(b)].



a

b

Figure 25(a) shows the finest size class particles (Filter 6) from the SSW. These particles are also typically <0.2 microns in diameter [Figure 25(b)].

## 7.0 DISCUSSION AND CONCLUSIONS

There can be no doubt that high volume sampling according to wind direction is a useful extension to an atmospheric sampling programme.

This report and subsequent work have shown that the nature of particulates (inorganic versus biological, elemental composition, size distribution, stable isotopic composition) are highly dependent upon wind direction. Similarly, the concentrations and isotopic composition of sulphur dioxide depend upon wind direction. The differences in the various parameters are indicative of different sources.

There are many sources of particulates including rock flour, loess, volcanic ash, meteoritic dust, fly ash, and other industrial emissions. Sulphur dioxide may come from industrial stacks or oxidation of biogenic hydrogen sulphide. It was not the intention of this study to identify specific sources. However, the techniques which have been tested demonstrate that such identifications are feasible.

An issue that arises in atmospheric sampling concerns the variation of wind direction with elevation. Winds at ground level may not move in the same direction as winds aloft. Therefore, pollutants may reach a monitoring site from a direction which differs from that of the line of sight from the source. On the other hand, the behaviour of pollutants at ground level bears most directly on environmental concerns. In cases where the array does not provide line of sight identification of sources, it is nevertheless useful to use ground level wind direction as a separation technique. The results of the current study show that

sampling irrespective of wind direction sacrifices information.

Ideally, supporting air current data would optimize the information obtained with the ground level sampling array. The absence of these data can, to some extent, be compensated by the analytical techniques of this report. Thus, sulphur isotope composition, SEM, etc., can be used to identify sources and in turn reveal the complexity of the wind behaviour. In principle, the techniques of this report could document ground level meteorological anomalies that are not predicted by extensive atmospheric modelling programmes.

Although the current study emphasized sulphur-containing compounds, the concept of wind directionally controlled sampling as a separation technique should yield similar benefits in studies of other atmospheric pollutants, e.g., nitrogen oxides, lead and other heavy metals, radionuclides, acid precipitation.

## 8.0 RECOMMENDATIONS

(1) The mechanical weather vane, anemometer, and relays proved expensive and unreliable. It is recommended that the controller be replaced by a microprocessor-based system incorporating solid state optically isolated relays, and sonic anemometers, for measuring wind speed and direction.

(2) Although 8 hivol samplers corresponding to the NNE, ENE, ESE, SSE, SSW, WSW, WNW, and NNW sectors of the compass provide better resolution, it would be desirable to have the flexibility of separating the

array into 2 sub-arrays which could be set different sites or at different elevations ; same site.

(3) An obvious extension of the system is the city of sampling precipitation by event. In this wole isotopes and other analytical techniques ce used to relate wet and dry deposition events tous sources.

## ACKNOWLEDGEMENTS

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Drs. Stuart Smith, Harby Sandhu, Bill MacDonald and Ali Kahn are to be commended for recognizing the potential of stable isotope techniques in providing a clearer understanding of the fate of air pollutants in Alberta.

Technical personnel involved in the project include Nenita Lozano (mass spectrometer), Ludmila Yakobi (mass spectrometer), Jesus Pontoy (sample preparation), Michael Yakobi (electronics), and Bruce McLean (sample collection). Dorothy Johnston conducted the scanning electron microscopy and electron probe x-ray fluorometry. Drafting and photographic prepartation was completed by Bill Matheson of Commedia, The University of Calgary.

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POOR

QUALITY

ORIGINAL